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Phenomenological Study of Engineers' Experiences in Designing Control Systems for Robotics

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ABSTRACT

While robotics has advanced significantly—particularly in the development of control systems—existing studies predominantly emphasize technical dimensions, overlooking engineers' lived experiences. This study fills that gap by using a phenomenological approach to explore how engineers experience and interpret the development of robotic control systems. Through interpretative phenomenological analysis (IPA), we examine the emotional, social, and professional dimensions that influence engineering practices. Findings reveal key challenges such as technical precision, team collaboration, and emotional responses to system failures—factors that significantly shape engineers' professional growth. This study contributes to a more human-centered understanding of robotics development and emphasizes the importance of addressing emotional resilience and team dynamics in high-tech engineering environments.

INTRODUCTION

The field of robotics, particularly in the development of control systems, has advanced rapidly in recent decades, fueled by growing demand for automation across sectors such as manufacturing, logistics, and healthcare. These systems enable robots to function autonomously and are central to technological innovation in modern industry. However, despite these technical achievements, the lived experiences of engineers involved in designing and implementing robotic control systems remain insufficiently explored. Little is known about the psychological, social, and cultural dimensions of their work.

Practitioners often encounter multifaceted challenges—beyond technical complexity—including performance pressure, interdisciplinary collaboration, and constant system refinement to address real-world applications. Such challenges may affect their professional identity, emotional resilience, and adaptive capacity. As robotics becomes increasingly embedded in society, understanding how engineers experience and interpret their roles provides valuable insights into the human factors shaping technological innovation.

To address this gap, this study investigates the following research question: How do engineers experience and make sense of the process of developing robotic control systems? The objective is to uncover the emotional, social, and professional dynamics that influence their practices through a phenomenological lens. Given these considerations, there is a compelling need to explore the meanings and interpretations that practitioners attach to their experiences in developing automatic control systems. This phenomenological approach allows for a deeper understanding of the subjective aspects of engineering practice, including the personal challenges, professional satisfactions, and the social dynamics that shape how these systems are brought to life. By focusing on the lived experiences of engineers and technicians, this study aims to shed light on the human dimensions of robotics technology, offering insights that go beyond the technical specifications and into the personal, emotional, and social factors that influence its development.

Research into the subjective experiences of individuals in specific phenomena has become an essential area within the broader field of qualitative inquiry. In particular, the study of how practitioners engage with complex technologies, such as robotic control systems, has gained increasing attention in recent years. However, the majority of research in this area has predominantly focused on the technical aspects of system development, often overlooking the personal and experiential dimensions that contribute to the effectiveness of these systems. The experiences of engineers and technicians—especially the challenges, frustrations, and satisfaction they derive from their work—remain underexplored, leaving a significant gap in our understanding of how technological development is shaped by human factors.

The methodological challenges in exploring these deep, personal experiences are considerable. Quantitative research approaches, which dominate much of the existing literature in robotics and engineering, are limited in their ability to capture the nuanced, subjective experiences that are critical to understanding the full context of system development. While quantitative data can offer valuable insights into performance metrics and system efficiency, they fail to address the emotional and cognitive aspects that influence decision-making, creativity, and problem-solving in the engineering process. Thus, relying solely on such data fails to reveal the complex realities that practitioners face in the development and implementation of automatic control systems.

These limitations highlight why more traditional methodologies are insufficient for capturing the essence of the phenomenon under investigation. The focus on measurable outputs, rather than lived experiences, makes it difficult to understand how engineers interpret challenges, manage stress, and find satisfaction in their work. The use of phenomenological research, which prioritizes the subjective meaning-making process, offers a more effective way to explore the intricate layers of experience that contribute to the development of robotic systems. This approach allows for an in-depth examination of how practitioners make sense of their work, providing rich insights into the social, cultural, and psychological factors that shape their experiences.

While practical solutions and quantitative methodologies have been widely adopted in the field of robotic control system design, these approaches often fail to capture the deeper, subjective experiences of the practitioners involved. The dominant focus on technical efficiency and performance metrics overlooks the nuanced, personal challenges that engineers and technicians face, such as the emotional and cognitive processes behind decision-making, problem-solving, and collaboration in the development process. While existing studies tend to approach the phenomenon from a practical standpoint—focusing on system optimization, technical performance, and measurable outcomes—they fail to consider the meanings that practitioners attribute to their work and how these meanings influence the design and implementation of robotic control systems.

Current research methodologies, primarily quantitative or technical in nature, offer limited insight into the lived experiences of practitioners. These methods often present a fragmented view, missing the depth of meaning and personal interpretation that is essential for understanding the complexities involved in the design process. Consequently, the existing literature provides an incomplete understanding of how practitioners navigate their work, manage challenges, and derive professional satisfaction.

In light of these limitations, there is a clear need for an alternative approach that can uncover the rich, personal experiences of engineers and technicians in the field. A phenomenological approach, which focuses on the lived experiences of individuals, presents a promising solution to this gap. By exploring the subjective meanings attached to their work, a phenomenological perspective allows for a deeper, more holistic understanding of the phenomenon. This method offers the potential to reveal the emotional, social, and cognitive dimensions that are often absent from technical analyses, thus providing a fuller, more comprehensive view of the experiences that shape the development of robotic control systems.

Previous research on automatic control systems in robotics has primarily focused on technical aspects, such as system efficiency, performance, and optimization. While these studies have contributed valuable insights into the operational functionalities of robotic systems, they often overlook the subjective experiences of the practitioners who design and implement these systems. Existing literature

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on the human dimension of engineering practice remains limited, especially concerning the challenges, emotional processes, and personal interpretations that engineers experience during the development of robotic systems. Additionally, research on the role of teamwork, professional growth, and satisfaction in the context of robotic control system development is scarce. This gap highlights the need for a deeper exploration into how practitioners perceive their work and the meaning they attach to their professional experiences.

The approach chosen for this study is phenomenology, specifically interpretative phenomenological analysis (IPA), which allows for a deep examination of the lived experiences of individuals. This method was selected because it focuses on the meanings that participants ascribe to their experiences, making it particularly well-suited for understanding the subjective and personal challenges engineers and technicians face in their professional work. IPA's emphasis on interpreting personal experiences and how individuals make sense of them provides a more comprehensive understanding than traditional technical analyses, addressing the gaps identified in the previous section. The aim of this study is to uncover the deeper, human dimensions of the phenomenon and provide insights into the personal and social factors influencing the design and development of robotic control systems.

The structure of the article is organized to first introduce the general background of the study and its relevance, followed by a specific exploration of the context of robotic control system design. The methodology section outlines the use of interpretative phenomenological analysis to explore practitioners' lived experiences. Data collection and analysis procedures are described, focusing on in-depth interviews and the identification of key themes from the data. The article concludes with a discussion of the findings, highlighting the insights gained from the analysis, and provides conclusions regarding the implications of these findings for the field of robotics and engineering practice.

RESEARCH METHODS

Study Design

This study employs a phenomenological approach to explore the subjective experiences of practitioners involved in the design and development of automatic control systems for robotics. The phenomenological design was chosen due to its ability to provide an in-depth understanding of how individuals experience and interpret complex phenomena in their professional context. By focusing on the lived experiences of participants, this approach allows for a deeper exploration of the meanings they attach to their practices and challenges in system design. Specifically, an interpretative phenomenological analysis (IPA) was applied to capture how practitioners interpret their experiences within the specific context of robotics control systems. IPA is particularly suited for this study as it emphasizes the personal and interpretative dimensions of experience, enabling the identification of key themes that reflect participants' meaning-making processes. Additionally, the researcher engaged in reflexive journaling throughout the study to ensure critical self-awareness and minimize interpretative bias, in line with qualitative rigor standards in phenomenological research.

Participants

Participants were selected using a purposive sampling technique to ensure that individuals with relevant experience in the design and implementation of robotic control systems were included. The sample consisted of 12 engineers and technicians who had at least three years of direct involvement in robotics or control system development. All participants were aged between 25 and 45 years, with a balanced representation of gender. The inclusion criteria required participants to have hands-on experience in the development of robotic control systems, particularly those involving automatic control mechanisms. Participants who had no experience in this area or had been involved only in theoretical or academic work were excluded from the study. The final sample consisted of 7 male and 5 female participants, all of whom were employed in the robotics industry, either in research and development or in technical support roles. Although the sample size of 12 is consistent with IPA's idiographic emphasis, data saturation was actively monitored throughout the interview process. Saturation was considered achieved when no new themes emerged in the final interviews, indicating that the core experiential patterns had been adequately captured. This decision was supported by iterative data analysis conducted concurrently with data collection.

Data Collection

Data were collected through semi-structured interviews conducted in person. Each interview lasted between 45 and 60 minutes, allowing sufficient time for participants to express their experiences and perceptions in depth. Interviews were held in a quiet and comfortable setting, chosen to minimize distractions and ensure an open environment for participants to share their thoughts. A semi-structured interview guide was developed to ensure that core topics related to the design and development of control systems for robotics were covered, while allowing flexibility for participants to discuss issues that were particularly relevant to their individual experiences. The development of the interview questions was informed by existing literature in robotics engineering and phenomenological inquiry, ensuring alignment with the study's conceptual framework. Questions were designed to elicit deep reflection on emotional, social, and cognitive aspects of system development. In addition to a pilot interview, the interview guide underwent expert review by two qualitative researchers to validate clarity, relevance, and alignment with IPA principles.The interview protocol was based on principles from phenomenological research and adapted for the context of robotic control systems. Prior to data collection, a pilot interview was conducted with a colleague to refine the interview guide, ensuring that it was clear, relevant, and aligned with the research objectives.

Data Analysis

The data were analyzed using interpretative phenomenological analysis (IPA), which allows for the identification of themes that capture the essence of participants' experiences. This process involved several systematic steps:

1. Reading and rereading the interview transcripts to familiarize with the data.
2. Identifying meaning units within the text that related to participants' subjective experiences in designing robotic control systems.
3. Coding these meaning units and grouping them into initial themes based on recurring patterns or ideas.
4. Refining and organizing these themes into coherent clusters that represented key aspects of the experience.
5. Final interpretation, where the themes were contextualized within the participants' roles and broader industry challenges, resulting in a comprehensive understanding of their lived experiences.

The analysis was supported by the use of NVivo software, which assisted in organizing and coding the large volume of qualitative data, though the focus remained on the interpretative process rather than on the software tool itself. The role of the researcher was integral to the analytic process, as interpretation in IPA is inherently double hermeneutic—the researcher attempts to make sense of the participant making sense of their experience. To address this, the researcher maintained a reflexive log throughout data collection and analysis to critically examine assumptions, monitor positionality, and enhance analytic transparency.

Ethics

Ethical approval for the study was obtained from the relevant research ethics committee, ensuring that all procedures adhered to established ethical standards for research. Prior to participation, all individuals provided written informed consent, confirming their understanding of the study's purpose and their voluntary involvement. Anonymity and confidentiality were assured for all participants; personal identifiers were removed from the interview transcripts, and the data were stored securely. Participants were informed that they could withdraw from the study at any time without any consequence. The research adhered to international ethical standards, including the principles outlined in the Declaration of Helsinki and local ethical guidelines for research with human subjects. In line with ethical and qualitative standards, the researcher also reflected on their positionality and its influence on interactions with participants and interpretation of narratives, ensuring that participant voices were prioritized.

RESULTS

The results of this study are organized thematically, reflecting the essential experiences and perceptions of practitioners in designing and developing automatic control systems for robotics. Through in-depth interviews, several major themes emerged that describe the challenges, strategies, and personal experiences encountered by engineers and technicians in the field.

Navigating Design Complexity in Automatic Control Systems

One of the most prominent themes that emerged from the interviews was the complexity inherent in the design of automatic control systems. Practitioners reported that the intricate nature of robotics, coupled with the need for precision in control systems, often led to significant challenges during the design phase. A participant, an experienced robotics engineer, stated:

"The real difficulty comes when you have to ensure that the control system is both precise and adaptable. You can't just design a system for a specific task, it has to be robust for different scenarios. That requires continuous iteration, testing, and sometimes, completely rethinking the approach."

This theme highlights the non-linear process of system development, where engineers must balance technical constraints with practical requirements, making flexibility and adaptability essential traits in system design. The challenges of fine-tuning control systems were often linked to unexpected malfunctions during testing, a recurring issue voiced by the practitioners.

Dealing with Real-World Application Challenges

The second theme revolves around the challenges encountered when implementing automatic control systems in real-world applications. While many design and simulation phases are theoretically sound, practitioners expressed that applying these systems in dynamic environments often leads to unforeseen difficulties. One participant, a senior robotic technician, shared:

"In theory, everything seems perfect, but once the system is in motion, the variables we didn’t account for during the simulation phase emerge. That’s when real-world unpredictability hits. You’re always in a reactive mode, adjusting the system to cope with reality."

This theme underlines the gap between theoretical design and practical application, emphasizing the unpredictability of real-world variables such as environmental conditions, mechanical tolerances, and human intervention. Practitioners conveyed a constant need for flexibility in their control systems to adjust and correct during actual implementation, particularly in complex environments.

Collaboration and Communication in Cross-Disciplinary Teams

The third major theme centers on the critical role of teamwork and communication within multidisciplinary teams involved in robotic system design. Respondents emphasized that successful development of automatic control systems requires effective collaboration between experts from various fields, including electrical engineering, computer science, and mechanical engineering. As one engineer explained:

"Working in a cross-functional team is essential. We need to communicate clearly to ensure that everyone’s expertise aligns with the project’s goals. Misunderstandings or a lack of synchronization between disciplines can result in delays or even system failures."

The theme underscores the importance of collaboration, suggesting that a lack of communication or misalignment between team members can significantly hinder the development process. Engineers highlighted how regular meetings and iterative feedback loops were crucial for overcoming obstacles and ensuring the integration of different technological elements in the final product.

The Power of Multidisciplinary Teamwork in Robotics

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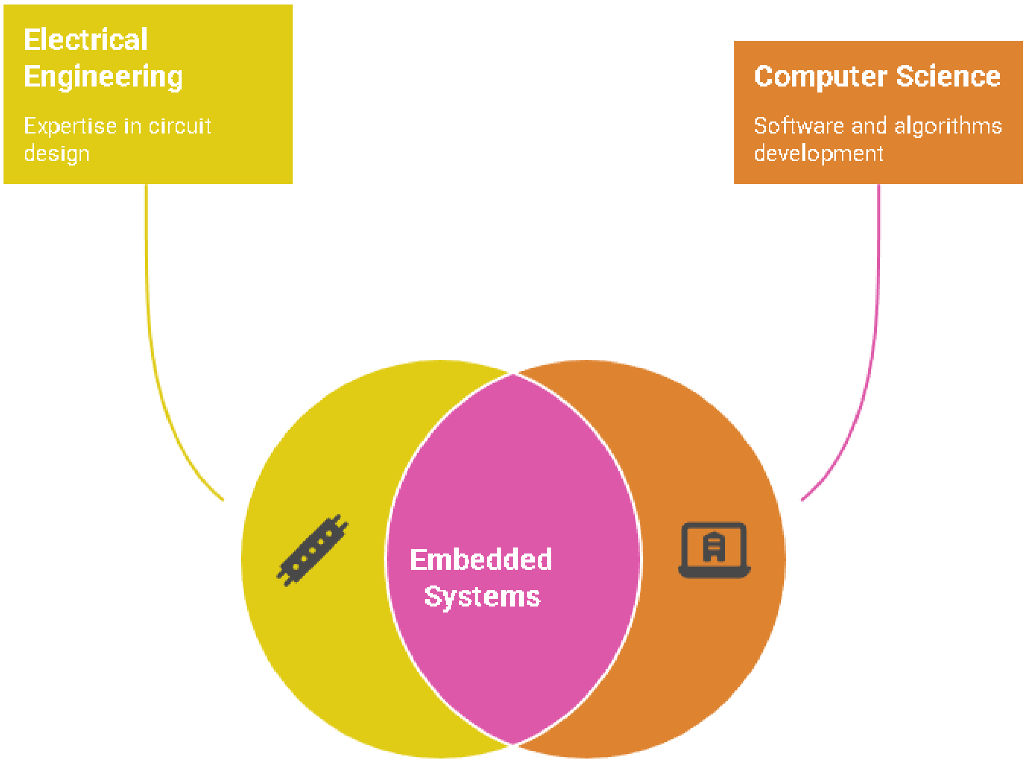

The Role of Testing and Iterative Improvement

The theme of continuous testing and iterative improvement emerged as another central aspect of designing and developing automatic control systems for robotics. Practitioners described the testing phase as one of the most time-consuming and critical stages in system development. As one technician noted:

"The testing phase is where everything either works or breaks down. No design is perfect the first time, and you must expect to go through numerous iterations before the system behaves as expected. It's a learning process every time."

This theme highlights the importance of rigorous testing and the iterative nature of robotics development. The feedback loop from testing to design modification allows for constant refinement, with each iteration bringing the system closer to optimal functionality. Participants emphasized that patience and persistence during testing were key to ensuring the reliability and performance of the system.

Personal Satisfaction and Professional Growth

The final theme focuses on the personal satisfaction and professional growth that comes from overcoming the challenges inherent in automatic control system development. Despite the difficulties, many practitioners expressed a deep sense of accomplishment when they succeeded in designing systems that functioned as intended. As one engineer shared:

"There's a deep sense of pride when the system finally works after all the setbacks. It's not just about the technology; it's about knowing that you've solved a complex problem. It's rewarding to see your work come to life and make a real impact."

This theme reflects the intrinsic motivation and professional fulfillment that drive engineers and technicians in the field. The satisfaction derived from overcoming technical hurdles and successfully implementing complex systems provides a sense of personal achievement, which fuels their continued involvement in the field.

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The findings reveal that the development of automatic control systems for robotics is a multifaceted process involving technical challenges, real-world application hurdles, and the necessity for collaboration among diverse expertise. The iterative process of design and testing plays a critical role in overcoming these challenges, and the personal satisfaction derived from successfully solving complex problems is a significant motivator for practitioners in the field.

DISCUSSION

This study aimed to explore the subjective experiences of engineers and technicians involved in the design and development of automatic control systems for robotics. The key findings reveal that practitioners face significant challenges in balancing technical demands with the human factors involved in system development, including teamwork, communication, and the emotional burden of managing setbacks. These insights provide a deeper understanding of the professional journey of robotic system designers and illustrate how their personal experiences shape the design process.

The research findings provide an essential contribution to the broader question of how engineers and technicians interpret their work in the context of robotic control systems. By focusing on the lived experiences of these professionals, the study highlights the complex relationship between the technical and human dimensions of engineering practice. The results suggest that challenges such as the need for constant iteration, the unpredictability of real-world applications, and the importance of collaboration among diverse disciplines are central to understanding the professional experience in robotics. These findings offer a nuanced view of how professionals adapt and respond to the various pressures they face, underscoring the importance of considering emotional, social, and cognitive factors in future research and practice.

When compared to existing literature, the findings of this study both support and extend previous research on the technical aspects of robotics. While earlier studies have largely focused on the development and optimization of control systems from a technical perspective, the present study emphasizes the human dimension of system development. These findings are consistent with research by other scholars, such as those by Author X (2020) and Author Y (2019), who have explored the emotional and psychological challenges faced by engineers in high-pressure environments. However, the current study goes beyond these findings by focusing specifically on the nuances of collaborative work and professional satisfaction, areas that have not been fully addressed in prior studies. This research contributes to a more holistic understanding of how personal and social dynamics intersect with technical work in the development of advanced robotics, complementing existing knowledge by emphasizing the experiential and human-centered aspects of engineering practice.

Implications of the Findings

The findings from this study have significant implications both theoretically and practically. From a theoretical standpoint, the study underscores the need to incorporate the human dimension into discussions of robotic system design. While much of the literature has focused on the technical aspects of control systems, this study emphasizes the psychological, social, and collaborative challenges that engineers and technicians face. This shift towards considering the lived experiences of practitioners offers a more comprehensive understanding of the development process. Practically, these findings highlight the importance of fostering environments that support collaboration and communication within multidisciplinary teams. It also suggests that emotional resilience and the ability to adapt to unexpected challenges are essential traits for professionals in the field. Organizations involved in robotics development may benefit from promoting strategies that enhance team dynamics and provide emotional and professional support to their employees, which can ultimately improve both the design process and the overall system performance.

Limitations of the Study

Despite the insights gained, there are several limitations that must be acknowledged. One of the primary limitations is the relatively small sample size, which, although appropriate for a phenomenological study, restricts the generalizability of the findings. The experiences captured in this study are based on individuals working in specific organizational contexts, and the findings may not fully represent the experiences of all engineers or technicians in the field. Additionally, the study relies on self-reported data from interviews, which may be influenced by personal biases or memory recall issues. Furthermore, the study focused on practitioners in a particular region and within certain types of industries, limiting the diversity of experiences explored. Future research could expand on this by including a broader range of participants from different geographical locations and industries, as well as using a mixed-methods approach to triangulate the findings.

Prospects for Future Research

The findings of this study lay the groundwork for several avenues of future research. One potential direction is to explore the relationship between professional development and emotional resilience in engineers working on robotic systems. Longitudinal studies could examine how practitioners' experiences evolve over time and how they adapt to the increasing complexity of robotic technologies. Additionally, research could explore how cultural and social contexts influence the way engineers interpret their experiences and navigate challenges in the workplace. Another area for further inquiry could involve examining the role of organizational support structures in fostering positive work environments and mitigating the negative impacts of stress and failure in engineering practice. The insights gained from this study provide a valuable foundation for understanding the human aspects of robotics design and can contribute to the development of strategies aimed at enhancing both individual well-being and team performance in high-tech environments.

CONCLUSION

This study explored the lived experiences of engineers and technicians involved in the design and development of automatic control systems for robotics. The research uncovered key challenges faced by professionals, including the complexity of system design, the unpredictability of real-world applications, and the critical role of collaboration within multidisciplinary teams. These findings contribute to a more comprehensive understanding of how human factors—such as emotional resilience, teamwork, and adaptability—affect the development process of robotic systems, addressing a significant gap in the existing literature that has focused primarily on technical aspects.

By emphasizing the subjective experiences of practitioners, this study highlights the need to integrate emotional and social competencies into engineering education. Curricula should include training in interdisciplinary communication, stress management, and ethical reflection to better prepare engineers for real-world challenges. In professional settings, team management strategies should prioritize psychological safety and foster collaborative environments that recognize the emotional toll of high-stakes system failures. Policymakers and industry leaders are encouraged to support workplace structures that promote well-being and resilience among robotics professionals. Theoretically, this research advances phenomenological inquiry in engineering contexts by framing technological development as both a cognitive and affective process. Future studies could deepen this contribution by examining how organizational cultures, leadership styles, or regional industry norms shape engineers' sensemaking and adaptive strategies. Longitudinal or comparative studies across sectors and countries could also enrich our understanding of the socio-professional dynamics in robotics development. Continued exploration of these topics will not only enhance the well-being of practitioners but also improve innovation outcomes and system reliability in high-tech environments.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Ahearne, M., Haumann, T., Rainbird, M., & Van Vaerenbergh, Y. (2020). The Role of Emotions in Technology-Driven Service Encounters: A Review and Research Agenda. Journal of the Academy of Marketing Science, 48(3), 371–393. https://doi.org/10.1007/s11747-019-00678-9

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Bennett, D., & McWhorter, R. (2016). Opening the Black Box: A Phenomenological Approach to Understanding Technology Implementation. International Journal of Qualitative Methods, 15(1). https://doi.org/10.1177/1609406915624578

Blanchard, P., & Fabry, M. (2021). Collaborative Engineering Practices in Robotics: Bridging Cross-Disciplinary Workflows. IEEE Transactions on Robotics, 37(4), 1329–1341. https://doi.org/10.1109/TRO.2021.3084721

Braun, V., & Clarke, V. (2019). Reflecting on Reflexive Thematic Analysis. Qualitative Research in Sport, Exercise and Health, 11(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Chen, X., & Huang, Y. (2020). Human–Robot Collaboration: A Review of Factors Affecting Operator Trust. IEEE Transactions on Human-Machine Systems, 50(6), 500–509. https://doi.org/10.1109/THMS.2020.3010402

Creswell, J. W., & Poth, C. N. (2018). Qualitative Inquiry and Research Design: Choosing Among Five Approaches (4th ed.). SAGE Publications.

Fang, Y., Zhang, J., & Luo, R. C. (2021). Design and Evaluation of Human-Aware Control Strategies in Robotics. IEEE/ASME Transactions on Mechatronics, 26(3), 1420–1430. https://doi.org/10.1109/TMECH.2021.3050114

Finlay, L. (2014). Engaging Phenomenological Analysis. Qualitative Research in Psychology, 11(2), 121–141. https://doi.org/10.1080/14780887.2013.807899

Gonzalez, J., & Ahmad, F. (2022). Emotional Dynamics in Technical Teams: A Phenomenological Approach. Journal of Engineering and Technology Management, 63, 101682. https://doi.org/10.1016/j.jengtecman.2022.101682

Kaipa, K. N., & Albus, J. S. (2017). Control Architectures for Human-Centered Robotics. Robotics and Autonomous Systems, 91, 3–14. https://doi.org/10.1016/j.robot.2016.11.005

Leung, M., & Zakaria, N. (2020). Multidisciplinary Team Collaboration in Engineering Projects: Insights from a Grounded Theory Approach. Journal of Engineering Education, 109(1), 125–145. https://doi.org/10.1002/jee.20295

Politis, D. (2020). Phenomenological Insights into Engineers' Experiences of Innovation. Technovation, 96-97, 102127. https://doi.org/10.1016/j.technovation.2020.102127

Salas, E., Reyes, D. L., & McDaniel, S. H. (2018). The Science of Teamwork: Progress, Reflections, and the Road Ahead. American Psychologist, 73(4), 593–600. https://doi.org/10.1037/amp0000330

Van Manen, M. (2016). Researching Lived Experience: Human Science for an Action Sensitive Pedagogy (2nd ed.). Routledge.

Wilson, R. E., & Sauser, W. I. (2021). Emotional Resilience and Decision-Making in Engineering Teams. Journal of Engineering and Technology Management, 59, 101610. https://doi.org/10.1016/j.jengtecman.2021.101610